AD-A111 255 ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) F/G 4/1
MARITIME INFRARED PROPAGATION: PARTICLE SIZE DISTRIBUTION MEASU--ETC(U)
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ROYAL AIRCRAFT ESTABLISHMENT

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Technical Report 81111

September 1981

MARITIME INFRARED PROPAGATION: PARTICLE SIZE DISTRIBUTION MEASUREMENTS USING A HELICOPTER-BORNE AEROSOL COUNTER

by

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UDC 551.521.9 : 541.182.2/3 : 541.182.02

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Received for printing 14 September 1981

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SUMMARY

Particle size distribution measurements were made on nine successive days in late August 1980 using a PMS FSSP-100 aerosol counter flown on a Wessex Mk 5 helicopter. In all, 14 flights were made giving data at two heights, 30 and 100 ft above the sea surface, extending from our measurement site at Ardivachar Point on the island of South Uist in the Outer Hebrides out over the sea to a distance of 20 km. The results for the day, 25 August, on which the most truly 'maritime' conditions were experienced have been omitted since they are distorted by the helicopter flying through occasional very thin wisps of cloud well out to sea. Lumping together the data from the remaining days leads to the highly encouraging conclusion that the aerosol content of the atmosphere over the shallow water near the island does not differ significantly from that over deep water. The results also underline the crucial importance of air mass history and the power and value of the radon-counting technique.

Departmental Reference: Space 604

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1 INTRODUCTION

There is a need for synoptic data on infrared propagation in the maritime environment. For the UK, the particular need is for data typical of the open North Atlantic. Since it would be difficult and expensive to make propagation measurements *in situ*, the natural alternative is to seek a coastal or island site as a platform upon which to make the measurements. The presence of MOD land in the shape of the Royal Artillery rocket range on the island of South Uist in the Outer Hebrides makes this an obvious choice for a possible site. The question then arises of how typical the conditions at such a site are of the open sea - what disturbances are introduced by the island itself, such as spray generated by waves breaking on rocks?

The topic of maritime or near-sea infrared propagation is of special concern to Action Group 9 of TTCP Subgroup J. The various member countries, Australia, Canada, UK and US have been evaluating or characterising possible sites in their respective countries for the past 2 years or so, with the ultimate objective of instituting a collaborative measurement programme at one or more of these sites[1].

In the UK, Section Sp 3(d) of Space Department, has been characterising the South Uist site with assistance from UMIST (under contract to MOD) and from RSRE. An adequate attempt at the evaluation of the site began with a 2 week measurement programme in April 1980 which involved all three groups. A further measurement programme again involving all three groups took place for 4-5 weeks in August 1980. This was followed by two more 2-week programmes in December 1980 and February/March 1981 using the RAE equipment alone. With some minor deficiencies, this programme should provide a good spread of 'absolute' measurements over the four seasons, and also sufficient comparative data from different locations to allow height effects, tidal effects, the effects of spray from waves breaking on rocks, etc, to be disentangled.

One characteristic special to the Outer Hebrides is that the seabed to the west of the islands shelves very gradually for some 10-15 km before deep water is reached. There therefore seems to be a special need to discover whether the aerosol content of the atmosphere over the relatively shallow water near the coast of South Uist is significantly different from the aerosol content over deep water. It was a specific recommendation of TTCP-JAG9 that airborne aerosol measurements should be made in conjunction with *all* other site characterisation measurements.

It so happened that another RAE Department, namely Engineering Physics, had already installed and flown an aerosol counter on a helicopter as a preliminary step in helicopter icing studies. Engineering Physics Department were approached and agreed to undertake the task of flying the aerosol counter in an RAE helicopter from our land-based measuring site at Ardivachar Point on South Uist out to sea for a distance of 20 km.

2 INSTRUMENTATION

The airborne measurements were made using a PMS (particle measuring systems) type FSSP-100 aerosol counter specifically designed for airborne use. In its normal airborne rôle, the counter operates without an aspirator, and the flow rate is dependent on the

forward airspeed. The counter was mounted on the starboard armament platform of a Wessex Mk 5 helicopter based at RAE West Freugh. Previous experience in the helicopter icing studies had shown that in this location the probe sampled clean undisturbed air free from the effects of the rotor downwash provided the forward airspeed exceeded 40-50 kn. At the forward airspeed actually used, namely 90 kn, the volume sample rate is given as 14.22 cm^3/s (no doubt to more than adequate, or necessary, accuracy!).

The FSSP-100 aerosol counter, like most other such counters for measuring small particles, is an optical device which measures the signal scattered as each individual aerosol particle (solid or liquid) passes through the beam from a He-Ne laser; the acceptance solid angle of the detector optics is a hollow cone from 4^o to 22^o off forward scatter. For the FSSP-100 counter, there is an overall size capability of 0.5 to 47 μm diameter* divided into four overlapping size ranges each with 15 equally spaced channels as follows: range #0, 2 (3) 47 μm; range #1, 2 (2) 32 μm; range #2, 1 (1) 16 μm; range #3, 0.5 (0.5) 8 μm. The output of the aerosol counter is controlled by a PMS type DAS-32 data acquisition system which collects the data in a form suitable for storing on magnetic tape. With the DAS-32 each output or record consists of 20 successive subframes each of which contains counts in all 15 channels of whatever size range is selected. The range does not change within one record. In the 'autorange' mode the probe is cycled automatically through its four ranges in the sequence 0, 0, 1, 2, 3. The framing rate can be selected from eight possibilities, and the rate actually chosen represents a compromise between the desire properly to sample inhomogeneities (in which case most of the counts recorded will usually be zero) and the amount of tape used and the consequent need to change the tape. For the horizontal flights, rate 2, equivalent to a 0.5 s subframe, was chosen; this gives a record length of 10 s and a time interval of 50 s before the autorange sequence is repeated. This appears to have been adequate, except for the inhomogeneities encountered on 25 August. For the vertical profiles a faster rate seemed appropriate and rate 3 was chosen, giving a 0.2 s subframe, a record length of 4 s, and an autorange cycle of 20 s.

In flight the DAS-32 was interfaced to a Plessey MODAS which records the output in analogue form on magnetic tape. Afterwards, back at RAE, Instrumentation and Trials Department translated the data into digital form on CCTs, and Space Department then debugged and organised the data on the mainframe computer. As a final step the data was then compressed into record totals, *ie* the counts in the 15 size channels totalled over 20 subframes, together with the corresponding variances derived from the subframe counts in order to indicate the variability without referring to the subframe data. This data was then transferred to a Hewlett-Packard 98-45A desk-top computer which provided an excellent graphical output facility.

3 THE AIRBORNE MEASUREMENTS

Flights were made on nine successive days in late-August 1980, the 20-28 inclusive. For various reasons only one flight was made on four of these days; but two flights, one

* Instrument characteristics are conventionally stated in diameters, whereas it is more usual and more convenient to express the results in radii.

in the morning and one in the afternoon, were made on the remaining five days giving 14 flights in total. The details of the various flights are given in Table 1.

During this period the weather was generally unsettled; on seven of the days the flight observer noted the presence of rain or mist. The obviously relevant meteorological quantities are also given in Table 1. Temperature and relative humidity were determined manually every hour using an Assman aspirated psychrometer, since RAE's dew point measurement was faulty at this time. Barometric pressure, rain rate, wind speed and direction were recorded automatically by the RAE system[2] at 10 s or 100 s intervals, and the quantities given are the appropriate averages as nearly as possible over the period of the helicopter flight. The last column gives the 'radon' count determined manually by RAE every hour with a 20 min atmospheric sampling period, using equipment on loan from NRL. The figure quoted is the average of the two counts nearest to the helicopter flight. Its significance is that a high radon count, say >20 pCi/m^3, shows that the air mass has been subject to continental influence within the last day or two and will contain many small particles, some of which will be condensation nuclei and some of which will, no doubt, be carbonaceous and absorbing. Conversely a low radon count, say <5 pCi/m^3, indicates a much cleaner air mass which has been at sea and away from continental influence for a fair number of days. Table 1 shows that the helicopter flights encompassed a wide range of conditions; the relative humidity ranged from 62 to 94%, wind speed from 1.3 to 12.6 m/s, wind direction from nearly south (195^o) through west to north (2^o), and the radon count from very low (~1) to high (~40).

The intended flight plan, which is shown diagrammatically in Fig 1 has been classified into 'tasks' as follows:

Task 1: level flight at a height of 30 ft above sea level from the shore at Ardivachar Point on South Uist out to sea for a distance of approximately 20 km on a bearing of approximately 254^o,

Task 2: a return flight to the shore also at a height of 30 ft,

Task 3: a vertical profile over land to a height of 5000 ft or cloud base if lower at a rate of 1000 ft/min and 70 kn indicated forward air speed,

Task 4: level flight at a height of 100 ft, again out to 20 km,

Task 5: a vertical profile at sea similar to task 3,

Task 6: a return flight to the shore also at a height of 100 ft.

This plan was carried out on all of the flights with the sole exception of 25 August, pm, when the cloud base was so low that vertical profiles could not be attempted. Indeed the flight observer noted that cloud base apparently reached down to the sea surface in places well out to sea. Such obvious patches were of course avoided, but the helicopter nevertheless inadvertently passed through occasional thin wisps of cloud out to sea at both 30 and 100 ft which produced massive increases in the counts of the large cloud-type droplets on a timescale of the order of one record (10 s).

4 RESULTS

The objective of this Report is the limited one of obtaining an answer to the basic question: Does the aerosol size distribution over the relatively shallow water near the shore differ significantly from that over deep water? To this end only the horizontal runs at 30 and 100 ft are considered here, and analysis of the vertical profiles is deferred until later. The approach adopted is the simplest possible: for each height the data is divided into two parts which are as nearly equal as possible - 'shore' and 'sea'. To be explicit, the first half of the flight seawards at 30 ft (task 1) is 'shore' data and the second half is 'sea' data, while for the return flight shorewards (task 2) the first half of the data is 'sea' and the second half is 'shore'.

The overall average number densities for the four ranges separated into 'shore' and 'sea' data are given in Tables 2 and 3 for the 30 and 100 ft data respectively. The numbers given are the total number densities summed over all 15 size channels for a given range, and are therefore usually dominated by the counts in the first two or three channels. A slight caveat is in order here regarding the total number of densities since the lowest channel is the one most affected by drifts of the bias levels of the counter electronics. Indeed the manufacturer recommends that the lowest channel or channels should be ignored if other data covering the same size is available. In any case the complete size distribution is more informative and significant anyway. It would scarcely be practicable, however, to present 14 × 4 figures, like Figs 2 to 5, most of which would look almost identical.

Referring to Tables 2 and 3, it will be seen that the 'shore' and 'sea' number densities do not differ greatly, by less than a factor of 2 and usually by much less, with the solitary exception of 25 August. On this day the ratios between the 'sea' and 'shore' number densities were approximately 5, 15, 18 and 8 for ranges 0, 1, 2, and 3 respectively for the 30 ft data. The corresponding values for the 100 ft data are even higher, namely 10, 28, 28 and 19. It is not that the 'sea' densities in Tables 2 and 3 are particularly high on this day, indeed they appear no more than average, but that the 'shore' densities are extremely low. As already discussed in section 3 the greater 'sea' densities do not represent an overall increase in density out to sea; instead they are the result of the helicopter inadvertently flying through thin patches of cloud at sea at both 30 and 100 ft, leading to massive increases in particle density, particularly of droplets larger than 5 μm radius. These events occurred on a timescale of the order of one record (10 s).

It is of course no accident that 25 August is the day on which the air mass was cleanest and most 'maritime'. The radon count for that day is the lowest in Table 1. Indeed earlier in the day (09.40 to 10.00) the radon count was 0.86 pCi/m^3 - the lowest so far recorded at the site. At the same time the wind speed was very low (1.33 m/s is by far the lowest value in Table 1), the sea was glassy, and the relative humidity remained well over 90% throughout the day. Despite the high relative humidity, the visibility at times, particularly soon after the helicopter flight, was extremely high and probably well in excess of 100 km. There was also clear evidence of anomalous

propagation since the lighthouse on the island of Shillay, and indeed the whole island, were clear y visible apparently standing proud of the sea. The island itself, which is 23.5 km distant, is nominally below the horizon for straight-line propagation from ground level at our site at Ardivachar Point.

It could fairly be said that under the conditions of 25 August, relative humidity and visibility reversed their usual rôles of cause and effect. The relative humidity rose to such high values because the atmosphere was at times very clear - there were almost no nuclei upon which the water vapour could condense. Presumably cloud succeeded in forming wherever supersaturation was achieved.

The remaining results in Tables 2 and 3 usually show slightly greater densities for 'sea' as opposed to 'shore'. There are, however, some exceptions. For run 3 (21 August, pm) the shore densities are slightly greater at 30 ft but not at 100 ft. For runs 4 (22 August, pm), 7 (24 August, pm) and 13 (28 August, am) the shore densities are slightly greater at 100 ft but not at 30 ft. For run 6 (23 August, pm) the shore densities are slightly greater at both heights. Time plots of the various runs show some spatial or temporal variations but not to the extent present on 25 August. Whether any other data ought reasonably to be excluded could be deduced from a consideration of the variances and the sub-frame counts, but it seems unlikely that our conclusions would be significantly different. Certainly there is no obvious correlation between the different kinds of behaviour and the meteorological quantities in Table 1.

We have therefore concluded that the most meaningful results are to be obtained by taking overall averages for all the runs excluding only 25 August. Figs 2 to 5 present overall average dN/dr plots for 'shore' and 'sea' data at 30 and 100 ft respectively. The format used is a general one designed to accommodate all our particle size distribution data without any change of scale.

Although the dN/dr plot is fairly standard, some words of explanation may be in order here for the non-specialist. Suppose n(r)dr is the number density per unit volume (cm^3) of particles having radii between r and $r + dr$. The total number density of particles per unit volume having radii between the limits r_1 and r_2 is then

$$N(r_1;r_2) = \int_{r_1}^{r_2} n(r)dr \quad .$$

For a given size range the aerosol counter effectively gives 15 total number densities $\Delta N_1, \ldots \Delta N_{15}$ in the 15 size channels all of the same width Δr. Thus our measurement of $n(r) = dN/dr$ is $\Delta Ni/\Delta r$. It is given in mixed units $\mu m^{-1}\ cm^{-3}$ with Δr expressed in μm and the unit of volume as $1\ cm^3$. Each point is plotted with the x-coordinate as the radius of the centre of the channel on a logarithmic scale, and the y-coordinate as n(r) again on a logarithmic scale. The four different ranges of the FSSP-100 counter are distinguished by four different symbols. There will be a maximum of 60 points on each figure although some points will be missing if there are no counts in the corresponding channels.

Turning now to the actual results, Figs 2 and 3 show the 'shore' and 'sea' data at 30 ft. It is immediately clear that the two figures are almost identical except that there are slightly more large particles in the 'sea' data than in the 'shore' data. Exactly the same conclusions hold for the data at 100 ft given in Figs 4 and 5. Again comparing the densities at the two heights, there are slightly more particles at the lower height but this time the difference is spread more uniformly over all sizes of particle. The total number densities in the four ranges are among the statistics tabulated below the figures.

Since the total number densities in the various ranges on 25 August quoted in Tables 2 and 3 are not particularly high, it might be thought that the data for 25 August could have been included in the overall averages without any noticeable effect. This is not so, however, since the total number densities conceal a massive increase in the number density of particles larger than 5 μm radius by at least two orders of magnitude over the values in Figs 2 to 5.

Although the helicopter results are self-contained and the 'shore' vs 'sea' comparisons must remain valid, it is nevertheless of considerable interest to compare the helicopter results with corresponding results obtained on land. The data available and to hand is of course RAE's own results using the ASAS-300 and CSAS-100-HV counters on a 10m high open lattice tower[2]. The land data is obtained by putting together 30 blocks of autorange data (covering 50 min in time at 100 s/record) coinciding as nearly as possible with each of the 14 helicopter flights. Since no autorange data was obtained on the morning of 20 August, an extra 30 blocks from the afternoon were taken instead. This is unlikely to make any significant difference since the meteorological quantities in Table 1, and the non-autorange data, are very similar from morning to afternoon. Also 25 August has been included since the reasons for omitting it from the helicopter data are not valid for the land data. The overall dN/dr plot is shown in Fig 6 and clearly all the ranges of both probes are in excellent agreement. Comparing Fig 6 with Figs 2 to 5, there is good agreement between 1 and 5 μm although the land data shows higherr densities for particles smaller than 1 μm and larger than 5 μm. The writers believe that the land data is more likely to be correct below 1 μm because of the internal consistency of the data and because of the high correlation between the density of very small particles and the radon count[3]. The reason is believed to lie in the electronic rejection circuitry of the FSSP-100 which uses the pulse length produced by a particle passing through the He-Ne laser beam. It must be remembered that the FSSP-100 is designed for airborne use to measure cloud droplets. Which counter is more likely to be correct in the absolute sense above 5 μm must remain an open question for the moment.

The structured features, and in particular the oscillations in CSAS range 1, evident in Fig 6 between 0.5 and 5 μm are real in the sense that they arise from oscillations in the scattering efficiency factor, and in principle they contain information on the refractive index and absorption of the particles[2].

5 CONCLUSIONS

Section Sp3(d) of Space Department has been involved, with assistance from UMIST and RSRE, in characterising the area around Ardivachar Point on the island of South Uist in the Outer Hebrides as a possible site for measurements of infrared propagation in conditions typical of the open North Atlantic ocean. The use of an island site as a platform immediately poses the question of what disturbances the island itself will introduce. In particular one characteristic peculiar to the Outer Hebrides is that the seabed to the west of the islands shelves very gradually for some 10-15 km before deep water is reached. There therefore appears to be a special need to discover whether the aerosol content of the atmosphere over the relatively shallow water near the coast of South Uist differs significantly from the aerosol content over deep water.

In an attempt to answer this question, particle size distribution measurements were made on nine successive days in late-August 1980 using a PMS FSSP-100 aerosol counter flown on a Wessex Mk 5 helicopter. The intended flight plan, shown diagrammatically in Fig 1, consisted of outward and return flights from Ardivachar Point out to a distance of 20 km over the sea at two different heights, 30 and 100 ft above the sea surface, together with vertical profiles to 5000 ft (or cloud base if lower) both over land and over deep water at 20 km distance. This flight plan was carried through on all 14 actual flights with the sole exception of 25 August, pm, when the cloud base was so low that vertical profiles could not be attempted. Indeed the flight observer noted that cloud base apparently extended down to the sea surface in places well out to sea. Although such obvious patches were avoided, the helicopter at both heights nevertheless passed through occasional thin wisps of cloud which produced massive increases, usually lasting for a few seconds, in the number of droplets larger than about 5 μm in radius.

Although it might be possible to include data from 25 August, pm by a more detailed examination of the inhomogeneities, either by using the variances or by going back to the original subframe data - indeed this ought to be done for all the data - we have nevertheless concluded that the most meaningful results at this stage are to be obtained simply by omitting 25 August, pm and combining the data from all the remaining flights. To answer the basic question, we have considered only the horizontal runs at 30 and 100 ft and we have adopted the simple approach of dividing the data for each run, outward or inward, into two parts as nearly equal as possible - the part nearer the shore and the part further out to sea. The overall particle size distributions for 'shore' and 'sea' data at the two heights are shown in Figs 2 to 5. It is immediately clear that the particle size distributions are very similar. At both heights, there are slightly more large particles greater than 5 μm in radius in the 'sea' data than in the 'shore' data. Also, on comparing the two heights, there are slightly fewer particles at the greater height, but here the difference seems to be spread fairly uniformly over all sizes of particle. Our main conclusion is therefore the highly encouraging one that the aerosol content of the atmosphere over relatively shallow water near the coast of South Uist differs so little from that over deep water that the differences are scarcely significant.

Indeed it would appear that the presence of a gently shelving seabed to the west of the Outer Hebrides could be highly advantageous in reducing the wave height and thereby reducing the aerosol contribution from waves breaking on rocks and on the shore.

To return to the observations for 25 August, pm, it is of course no accident that on this day the air mass was the cleanest and most 'maritime' experienced. Earlier in the day, the radon count from the air sampled between 09.40 and 10.00 gave a value of 0.86 pCi/m^3 - the lowest value so far recorded at the site. Also the relative humidity remained well over 90% throughout the day. During the helicopter flight, the wind speed was very low and the sea glassy. Despite the high relative humidity, the visibility at times, particularly soon after the helicopter flight, was extremely high and probably well in excess of 100 km - St Kilda was clearly visible from higher ground on the return journey from the site. The reason is presumed to be that there were almost no nuclei present in the atmosphere upon which the water vapour could condense. Certainly at that time the number density of small particles of the order of 0.1 μm radius measured by the Space Department ASAS-300 aerosol counter on our 10 m tower at Ardivachar Point was two orders of magnitude lower than for the overall average shown in Fig 6. There was also clear evidence of anomalous propagation.

The results for 25 August only serve to emphasise the crucial importance of air mass history, in other words the number and nature of the small particles present in the atmosphere. Indeed a special study ought to be made of all data obtained on this day and on the two following days, during which period the radon count rose steadily to values in excess of 40 pCi/m^3 and the small particle count increased by between two and three orders of magnitude. The results also underline the power of the radon counting technique - it is a relatively simple measurement which provides the necessary corroboration and without which the results might at times even be doubted.

Acknowledgments

The writers wish to acknowledge their indebtedness to the many people who contributed at various times and in many ways to the success of this enterprise as follows:

(i) to the Helicopter Icing Section of EP2 who agreed to the use of their equipment, and in particular to Mr G.F. Barlow who operated the equipment and acted as flight observer in the helicopter,

(ii) to AW Department who agreed to the use of the helicopter for aerosol measurements in addition to its normal activities, in particular to Mr A.W. Linder and Mr W.G. Hasler at RAE, and Mr C.D. Hastings at West Freugh,

(iii) to AFM and Aircraft Department for the initial planning and organisation,

(iv) to Mr M.P.G. Walden of Designs Department for the installation of the equipment in the helicopter,

(v) to the aircraft servicing team from Field Aircraft Services at West Freugh,

(vi) to Mr S. Jones, the airfield manager at Benbecula, and to the Meteorological Staff,

(vii) to the Royal Artillery for the use of the site at Ardivacher Point and many other facilities, and

(viii) last but not least to the helicopter pilot and flight engineer, Mr D. Moffat and Mr J. Laird of Field Aircraft Services.

Table 1

DATES AND TIMES OF THE VARIOUS HELICOPTER FLIGHTS TOGETHER WITH AVERAGED VALUES OF THE VARIOUS METEOROLOGICAL PARAMETERS MEASURED ON LAND

Flight	Date	Time (GMT)		Temperature	RH	Barometer	Rain	WSPD	WD	Radon
		Start	End	°C	%	mb	mm/h	m/s	deg	[illegible]
1	20 August, am	09.15	10.10	14.5	76.0	998.7	0.00	12.59	288	[illegible]
2	20 " pm	12.51	13.42	14.0	74.0	1010.4	0.00	12.17	[illegible]	[illegible]
3	21 " pm	13.29	14.23	14.0	68.1	1019.3	0.00	9.51	[illegible]	[illegible]
4	22 " pm	15.18	16.10	12.8	68.0	1024.7	0.00	[illegible]	[illegible]	[illegible]
5	23 " am	09.29	10.23	13.5	62.0	1026.4	0.00	4.34	[illegible]	[illegible]
6	23 " pm	14.56	15.49	13.9	72.0	1025.6	0.00	4.17	[illegible]	[illegible]
7	24 " pm	13.14	14.23	14.8	85.5	1019.6	0.00	[illegible]	[illegible]	[illegible]
8	25 " pm	13.14	13.48	13.7	94.0	1017.7	0.01	1.33	[illegible]	[illegible]
9	26 " am	09.15	10.03	14.6	81.5	1016.7	0.00	5.96	[illegible]	[illegible]
10	26 " pm	13.08	13.59	15.6	78.5	1016.5	0.00	3.79	[illegible]	[illegible]
11	27 " am	09.24	10.19	15.3	80.0	1011.6	0.00	7.59	[illegible]	[illegible]
12	27 " pm	14.10	15.06	15.8	83.0	1010.2	0.00	7.57	201	[illegible]
13	28 " am	09.19	10.07	14.7	90.0	1008.4	0.00	7.65	246	[illegible]
14	28 " pm	14.04	14.54	15.2	89.5	1008.9	0.00	7.52	225	[illegible]

Table 2

TOTAL NUMBER DENSITIES IN THE FOUR RANGES, SEPARATED INTO SHORE AND SEA DATA, FOR THE HELICOPTER FLIGHTS AT 30 ft

Flight	Date	Shore				Sea			
		Probe range				Probe range			
		0	1	2	3	0	1	2	3
1	20 August, am	2.62	2.45	3.98	7.30	2.73	2.59	4.33	7.90
2	20 " pm	3.24	2.72	4.07	7.20	3.35	2.78	4.26	8.33
3	21 " pm	2.14	1.65	2.16	3.84	1.85	1.40	1.91	3.32
4	22 " pm	3.17	2.36	2.70	4.79	3.23	2.44	2.73	4.97
5	23 " am	1.03	0.84	0.66	1.19	1.04	0.85	0.64	1.16
6	23 " pm	1.71	1.27	1.37	2.37	1.38	1.08	1.03	1.86
7	24 " pm	2.57	2.03	2.37	4.23	2.95	2.30	3.06	5.47
8	25 " pm	0.21	0.16	0.17	0.12	1.05	2.41	3.00	0.98
9	26 " am	0.47	0.47	0.56	0.68	0.69	0.53	0.72	0.93
10	26 " pm	0.90	0.66	0.84	1.00	0.95	0.66	0.91	1.18
11	27 " am	2.88	2.13	3.53	5.40	3.41	2.50	5.13	8.13
12	27 " pm	2.05	1.65	3.36	4.53	2.54	2.22	4.68	6.94
13	28 " am	8.74	7.73	16.14	19.73	8.83	7.89	16.64	20.40
14	28 " pm	7.85	6.29	13.56	16.32	7.60	6.32	13.20	16.18

Table 3

TOTAL NUMBER DENSITIES IN THE FOUR RANGES, SEPARATED INTO SHORE AND SEA DATA, FOR THE HELICOPTER FLIGHTS AT 100 ft

Flight	Date	Shore				Sea			
		Probe range				Probe range			
		0	1	2	3	0	1	2	3
1	20 August, am	1.66	1.62	2.62	5.21	2.12	2.09	3.35	5.97
2	20 " pm	1.75	1.62	2.51	4.79	2.12	1.98	2.81	5.80
3	21 " pm	1.00	0.81	0.97	2.04	1.29	1.15	1.50	2.80
4	22 " pm	2.31	1.89	2.41	4.42	2.24	1.70	2.01	3.88
5	23 " am	0.95	0.69	0.64	1.08	0.94	0.72	0.67	1.18
6	23 " pm	1.11	0.90	1.01	1.86	0.99	0.78	0.87	1.49
7	24 " pm	2.57	2.44	3.31	5.84	1.85	1.70	2.27	3.27
8	25 " pm	0.17	0.18	0.17	0.15	1.70	5.05	4.75	2.77
9	26 " am	0.32	0.26	0.54	0.66	0.38	0.34	0.68	0.89
10	26 " pm	0.61	0.54	1.03	1.36	0.67	0.55	1.08	1.45
11	27 " am	1.73	1.60	3.39	5.06	2.25	2.03	4.76	7.59
12	27 " pm	1.36	1.21	2.73	3.83	1.75	1.56	3.73	5.32
13	28 " am	9.10	8.33	16.92	20.43	8.86	7.98	16.64	20.07
14	28 " pm	7.65	6.68	13.50	16.73	8.08	7.33	14.33	17.36

REFERENCES

No.	Author	Title, etc
1	-	Near-sea atmospheric propagation. Minutes of the 3rd meeting of TTCP-JAG9
2	R.R. Allan	Maritime infrared propagation: An interim progress report on the characterisation of a site in the Outer Hebrides. RAE Technical Report (to be issued)
3	R.R. Allan P.C. Ashdown	Maritime and continental aerosol particles. To be published

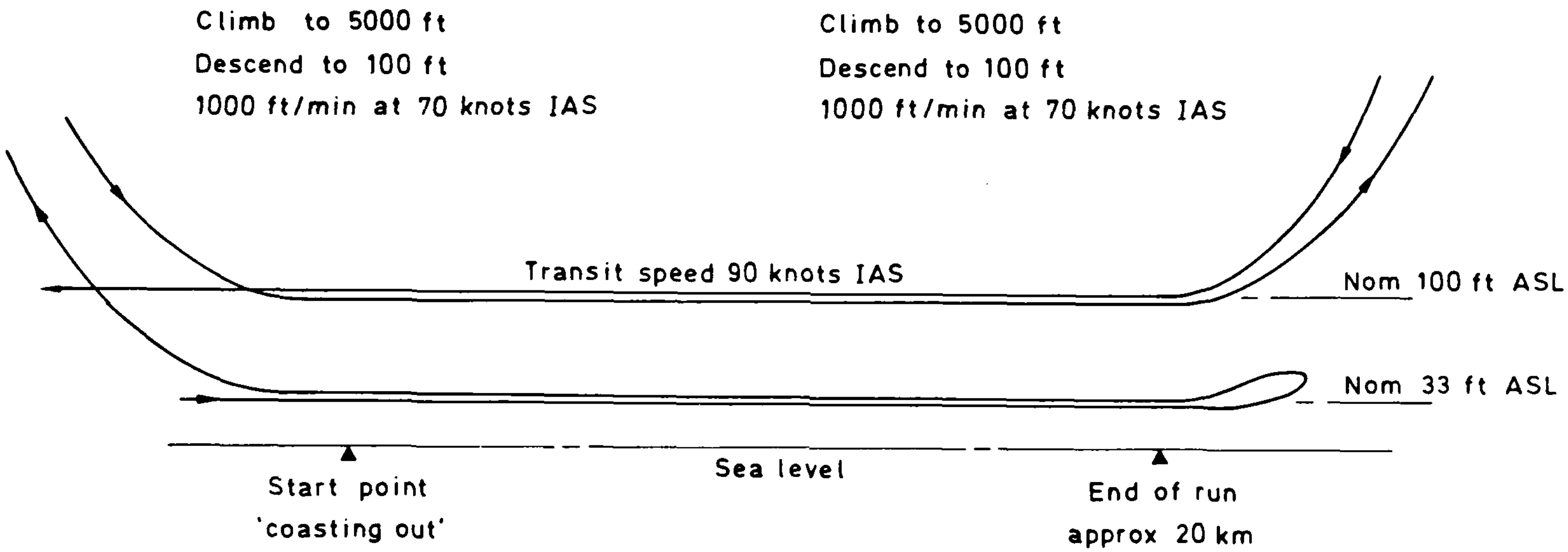
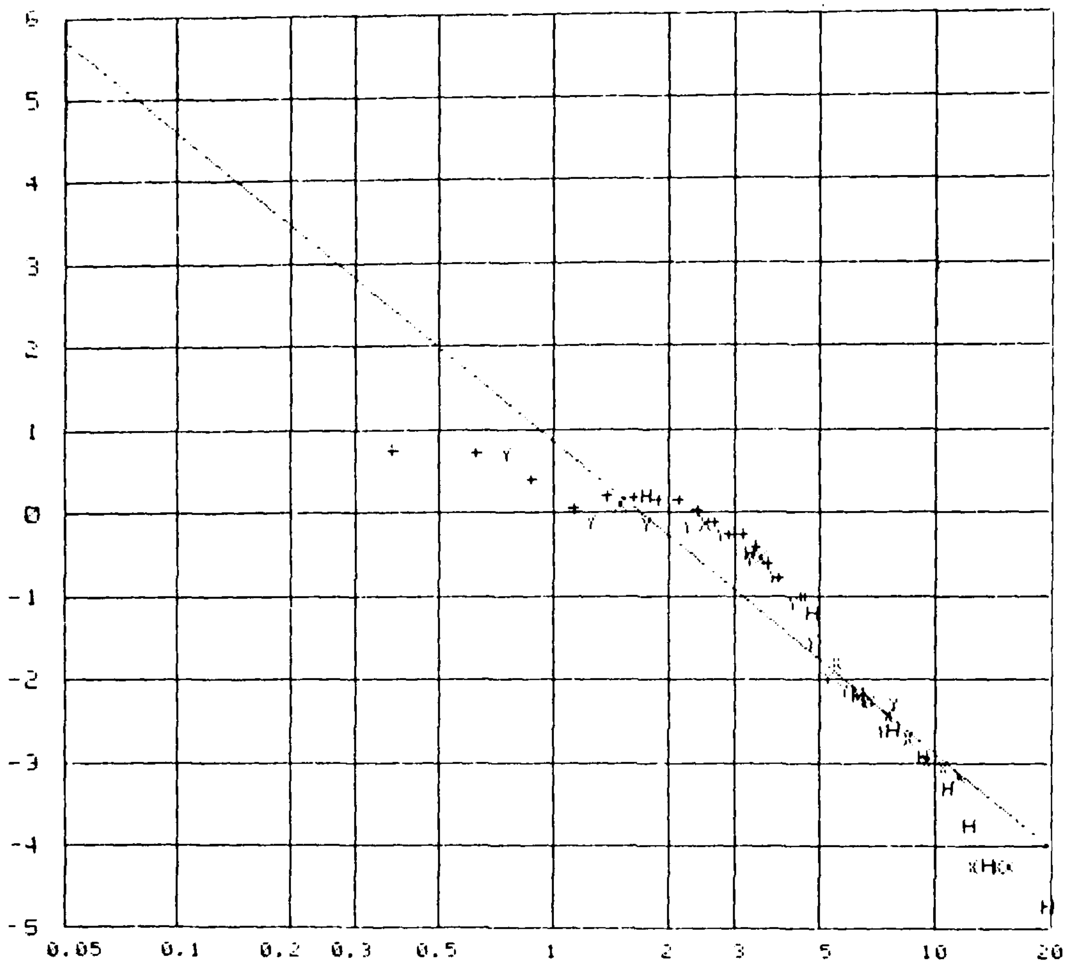


Fig 1 Intended profile for all helicopter flights

Fig 2



X: Radius(micron)
Y: Log10 (dCounts/cc/ dRadius(micron))

RAE ENG.PHYS./SPACE DEPTS., SOUTH UIST, AUGUST 1980
PMS FSSP-100 PROBE FLOWN ON WESSEX HELICOPTER
'SHORE' HALVES OF ALL LEGS EXCEPT AUGUST 25 : TASKS 1&2 AT 30 FEET

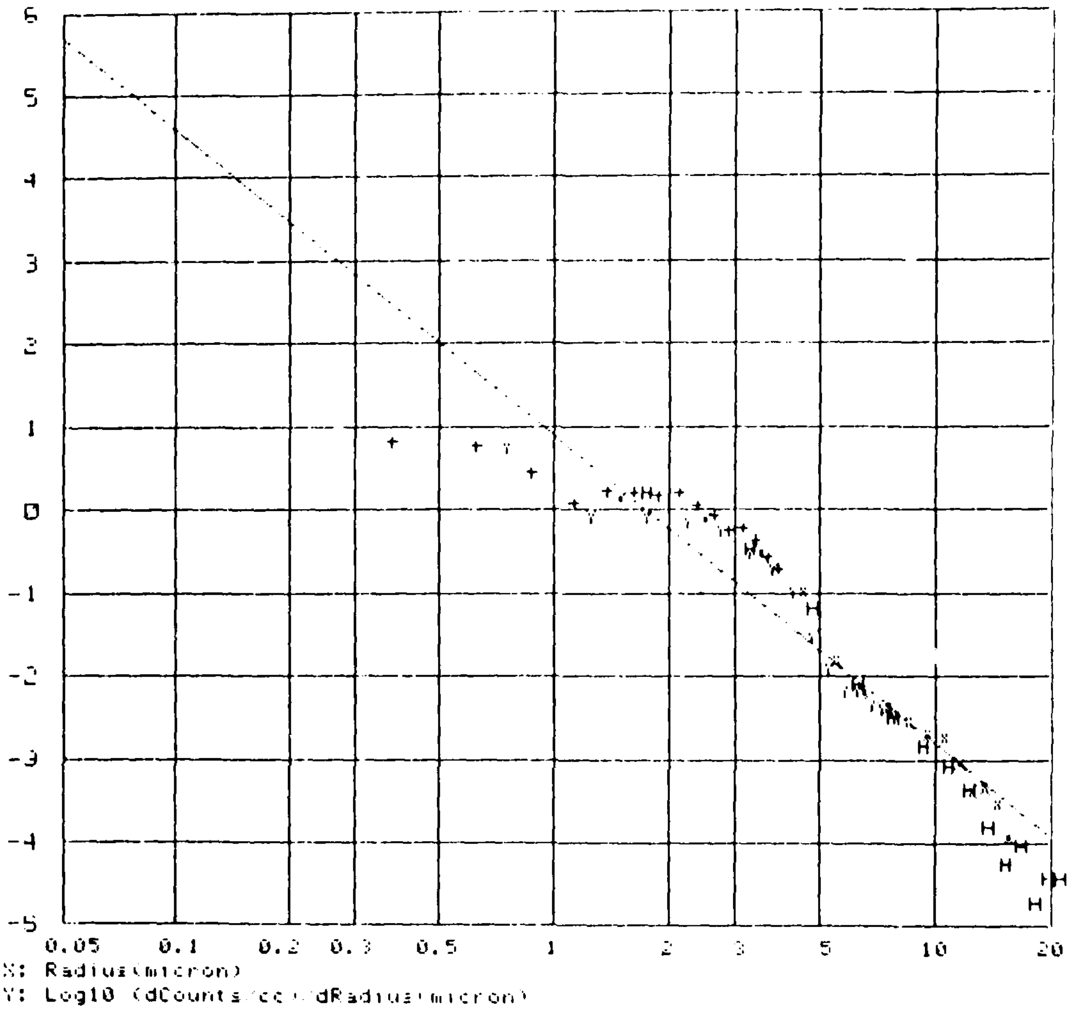
		Date	Time	Height		Date	Time	Height
START BLOCK	1	820	91519	30	END BLOCK 1307	828	142039	30

SPACE	ASAS#0	ASAS#1	ASAS#2	ASAS#3		CSAS#0		CSAS#1
EP/UNIST	ASAS#0	ASAS#1	ASAS#2	ASAS#3	FSSP#0	FSSP#1	FSSP#2	FSSP#3
No.TIMES SAMPLED	0	0	0	0	241	124	122	119
Tot.SAMPLE TIME	0	0	0	0	2410	1240	1220	1190
No.SIGN CHANGES	0	0	0	0	0	0	0	0
Tot.No.DENSITIES	0.00	0.00	0.00	0.00	2.97	2.45	4.19	6.0[illegible]
Symbol	*	#	0	I	H	X	Y	+

JUNGE EXPONENT IS -3.750 TOTAL NUMBER OF BLOCKS IS 606

Fig 2 Overall particle size distribution for helicopter flights excluding August 25: 'Shore' data at 30 ft

TR 81111



RAE ENG.PHYS./SPACE DEPTS., SOUTH UIST, AUGUST 1980
RMS FSSP-100 PROBE FLOWN ON WESSEX HELICOPTER
SEA HALVES OF ALL LEGS EXCEPT AUGUST 25 : TASKS 1&2 AT 30 FEET

		Date	Time	Height		Date	Time	Height
START BLOCK	1	820	91519	30	END BLOCK 1307	828	142039	30

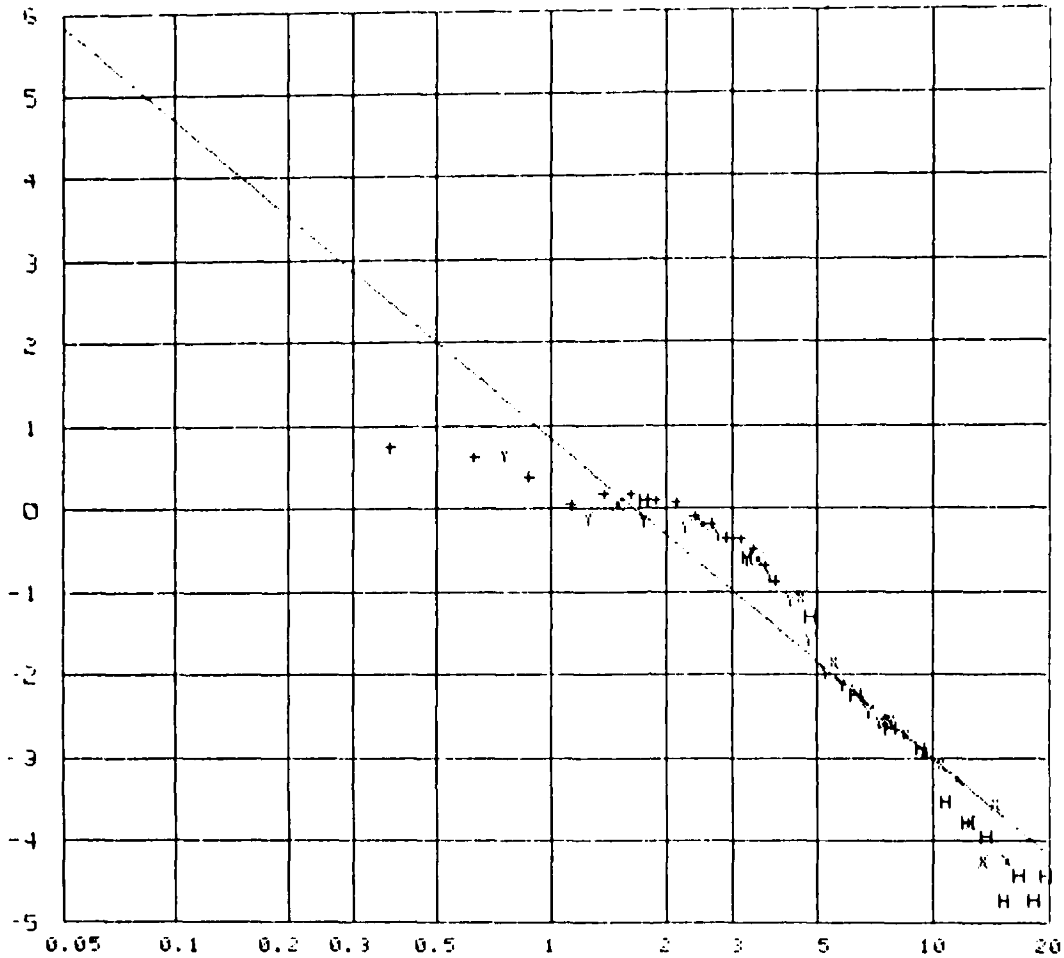
SPACE	ASAS#0	ASAS#1	ASAS#2	ASAS#3		CSAS#0		CSAS#1
EP UMIST	ASAS#0	ASAS#1	ASAS#2	ASAS#3	FSSP#0	FSSP#1	FSSP#2	FSSP#3
No.TIMES SAMPLED	0	0	0	0	244	121	120	124
Tot.SAMPLE TIME	0	0	0	0	2440	1210	1200	1240
No.SIGN CHANGES	0	0	0	0	0	0	0	0
Tot.No.DENSITIES	0.00	0.00	0.00	0.00	3.06	2.55	4.51	6.6
Symbol	+	#	0	I	H	X	Y	+

JUNGE EXPONENT IS -3.699 TOTAL NUMBER OF BLOCKS IS 609

Fig 3 Overall particle size distribution for helicopter flights excluding August 25: 'Sea' data at 30 ft

TR 81111

Fig 4



X: Radius(micron)
Y: Log10 (dCounts/cc) dRadius(micron)

RAE ENG.PHYS./SPACE DEPTS., SOUTH UIST, AUGUST 1980
PMS FSSP-100 PROBE FLOWN ON WESSEX HELICOPTER
SHORE HALVES OF ALL LEGS EXCEPT AUGUST 25 : TASKS 4&6 AT 100 FEET

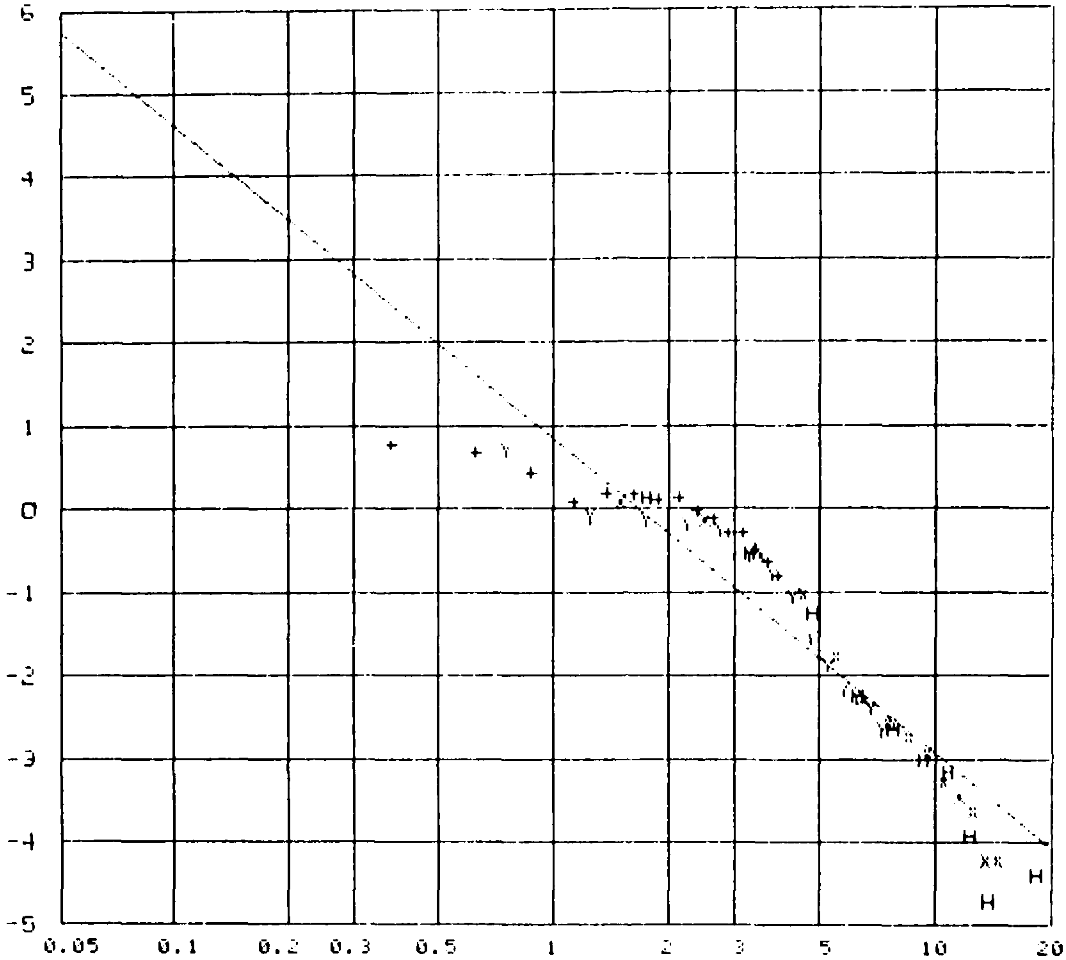
		Date	Time	Height		Date	Time	Height
START BLOCK	1	820	94426	100	END BLOCK 1352	828	145402	100

SPACE	ASAS#0	ASAS#1	ASAS#2	ASAS#3		CSAS#0		CSAS#1
EP UMIST	ASAS#0	ASAS#1	ASAS#2	ASAS#3	FSSP#0	FSSP#1	FSSP#2	FSSP#3
No.TIMES SAMPLED	0	0	0	0	250	126	129	125
Tot.SAMPLE TIME	0	0	0	0	2500	1260	1290	1250
No.SIGN CHANGES	0	0	0	0	0	0	0	0
Tot.No.DENSITIES	0.00	0.00	0.00	0.00	2.36	2.15	3.81	5.41
Symbol	*	#	O	I	H	X	Y	+

JUNGE EXPONENT IS -3.843 TOTAL NUMBER OF BLOCKS IS 630

Fig 4 Overall particle size distribution for helicopter flights excluding August 25: 'Shore' data at 100 ft

TR 81111



X: Radius(micron)
Y: Log10 (dCounts/cc)/dRadius(micron)

RAE ENG.PHYS./SPACE DEPTS., SOUTH UIST, AUGUST 1980
PMS FSSP-100 PROBE FLOWN ON WESSEX HELICOPTER
SEA HALVES OF ALL LEGS EXCEPT AUGUST 25 : TASKS 4&6 AT 100 FEET

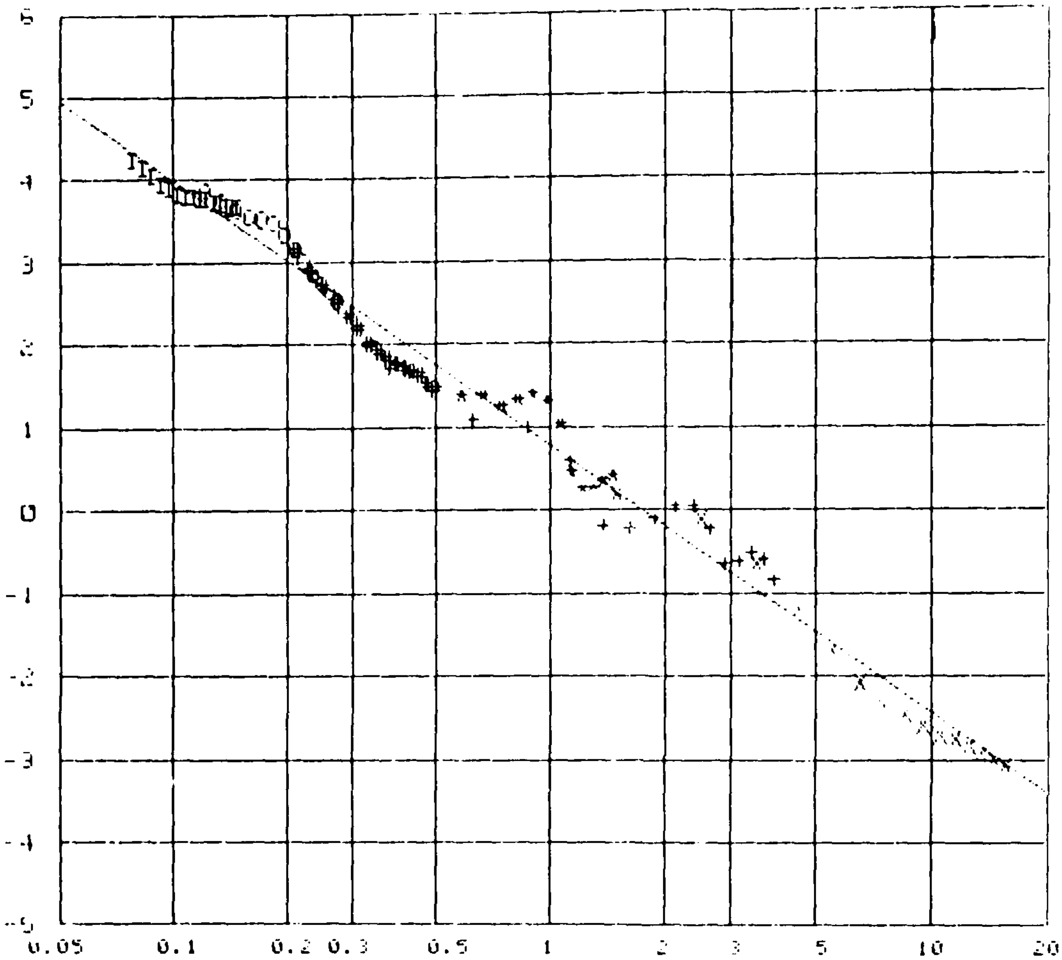
		Date	Time	Height		Date	Time	Height
START BLOCK	1	820	94426	100	END BLOCK 1352	828	145402	100

SPACE	ASAS#0	ASAS#1	ASAS#2	ASAS#3		CSAS#0		CSAS#1
EP UMIST	ASAS#0	ASAS#1	ASAS#2	ASAS#3	FSSP#0	FSSP#1	FSSP#2	FSSP#3
No.TIMES SAMPLED	0	0	0	0	249	124	126	130
Tot.SAMPLE TIME	0	0	0	0	2376	1186	1200	1240
No.SIGN CHANGES	0	0	0	0	0	0	0	0
Tot.No.DENSITIES	0.00	0.00	0.00	0.00	2.52	2.31	4.09	5.95
Symbol	*	#	O	I	H	X	Y	+

JUNGE EXPONENT IS -3.778 TOTAL NUMBER OF BLOCKS IS 629

Fig 5 Overall particle size distribution for helicopter flights excluding August 25: 'Sea' data at 100 ft

Fig 6



RAE TRIALS TEAM, ARDIVACHAR POINT, SOUTH UIST, AUGUST 1980
PMS ASAS-300 AND CSAS-100-HV PROBES ON 10 METRE TOWER
420 BLOCKS OF AUTORANGE DATA COINCIDENT WITH HELICOPTER FLIGHTS

		Date	Time			Date	Time
START BLOCK	1	820	130340	END BLOCK	420	828	145840

SPACE	ASAS#0	ASAS#1	ASAS#2	ASAS#3		CSAS#0		CSAS#1
EF UNIST	ASAS#0	ASAS#1	ASAS#2	ASAS#3	FSSP#0	FSSP#1	FSSP#2	FSSP#3
No.TIMES SAMPLED	170	83	82	85	0	252	0	168
Tot.SAMPLE TIME	17000	8300	8200	8500	0	25200	0	16800
No.SIGN CHANGES	0	0	0	0	0	0	0	0
Tot.No.DENSITIES	27.53	78.17	430.63	577.90	0.00	2.67	0.00	20.40

JUNGE EXPONENT IS -3.205

Fig 6 **Overall particle size distribution obtained from 420 blocks of autorange data taken on land on 10 m tower at Ardivachar Point, and approximately coincident with the helicopter flights**

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNCLASSIFIED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TR 81111	N/A	UNCLASSIFIED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aircraft Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	**6a. Sponsoring Agency (Contract Authority) Name and Location**
N/A	N/A

7. Title Maritime infrared propagation: particle size distribution measurements using a helicopter-borne aerosol counter

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Allan, R.R.	Craig, S.		September 1981	21	3
11. Contract Number	**12. Period**	**13. Project**	**14. Other Reference Nos.**		
N/A	N/A		Space 604		

15. Distribution statement

(a) Controlled by – Head of Space Department, RAE

(b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Aerosol. Maritime. Aerosol counter helicopter.

17. Abstract

Particle size distribution measurements were made on nine successive days in late August 1980 using a PMS FSSP-100 aerosol counter flown on a Wessex Mk 5 helicopter. In all, 14 flights were made giving data at two heights, 30 and 100 ft above the sea surface, extending from our measurement site at Ardivachar Point on the island of South Uist in the Outer Hebrides out over the sea to a distance of 20 km. The results for the day, 25 August, on which the most truly 'maritime' conditions were experienced have been omitted since they are distorted by the helicopter flying through occasional very thin wisps of cloud well out to sea. Lumping together the data from the remaining days leads to the highly encouraging conclusion that the aerosol content of the atmosphere over the shallow water near the island does not differ significantly from that over deep water. The results also underline the crucial importance of air mass history and the power and value of the radon-counting technique.

RAE Form A143

10/5/81

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